IMAGE DEFECT CORRECTION IN TRANSFORM SPACE

RELATED APPLICATION

This application relies on U.S. Provisional Application Serial No. 60/077,903 filed Mar. 13, 1998, and entitled "Image Defect Correction in Transform Space."

TECHNICAL FIELD OF INVENTION

This invention relates to electronic scanning of images, and more particularly to the scanning of photographic prints by reflected light and the removal of surface defects.

BACKGROUND OF THE INVENTION

The present invention is an improvement on a method of correcting defects in a film image using infrared light as taught in U.S. Pat. No. 5,266,805 issued to Albert Edgar, the present inventor. The underlying physics enabling this method is illustrated in FIG. **1**. In FIG. **1** it is noted that with any color of visible light, such as green light, one or more dyes in a color film absorb light with corresponding low transmission of the light; however, in the infrared wavelength range, the common image forming dyes have a very high transmission approaching 100%, and therefore have little or no effect on transmitted infrared light. On the other hand, most surface defects, such as scratches, fingerprints, or dust particles, degrade the image by refracting light from the optical path. This refraction induced transmission loss is nearly the same in the infrared as it is in the visible, as illustrated in FIG. **1**.

Continuing now with FIG. **2**, a film substrate **201** has embedded in it a dye layer **202**. Infrared light **204** (FIG. **2***a*) impinging on the film **201** will pass through the film and emerge as light **206** with nearly 100% transmission because the dye **202** does not absorb infrared light. Conversely, visible light **208** (FIG. **2***b*) will be absorbed by the dye **202**. If the dye density is selected for a 25% transmission, then 25% of the visible light **210** will be transmitted by the film **201**.

Now assume the film is scratched with a notch **214** (FIG. **2***c*) such that 20% of the light will be refracted from the optical path before penetrating into the film **201**. When a beam of infrared light **216** strikes the film **201**, 20% will be diverted due to the notch **214**, and a beam of 80% of the infrared light **218** will be transmitted. Finally, let a beam of visible light **220** (FIG. **2***d*) impinge on the film **201**. Again 20% of the light **222** is diverted by the notch **214**, leaving 80% of the visible light to penetrate the film **201**. However, the dye layer **202** absorbs 75% of that 80%, leaving only 25% of 80%, or 20% of the original light **224**, to pass through the film **201**.

In general, the beam left undiverted by the defect is further divided by dye absorption. In visible light, that absorption represents the desired image, but in infrared that dye absorption is virtually zero. Thus, by dividing the visible light actually transmitted for each pixel by the infrared light actually transmitted, the effect of the defect is divided out, just like division by a norming control experiment, and the defect is thereby corrected. This division process is further clarified in FIG. **3**. The value of a pixel **302** of a visible light image **304** is divided with operator **306** by the value of the corresponding pixel **308** of the infrared light image **310**. The resultant value is placed into pixel **312** of the corrected image **314**. Typically, the process is repeated with visible image **304** received under blue light, then green light, then red light to generate three corrected images representing the blue, green, and red channels of the image **304**.

FIG. **4** is similar to FIG. **3** in that it shows a process for removing the effect of defects from a visible light image **404** using an infrared light image **406**. Although the operator **408** in FIG. **4** is a subtraction, FIG. **4** is mathematically identical to FIG. **3** because the same result is obtained either by dividing two numbers, or by taking the logarithm of each, subtracting the two values in the logarithmic space, then taking the inverse logarithm of the result. However, the arrangement of FIG. **4** enables many additional useful functions because within the dotted line **402**, the signals from images **404** and **406** may be split and recombined with a variety of linear functions that would not be possible with the nonlinear processing using the division operator of FIG. **3**.

For example, in FIG. **5** a visible image **502** and an infrared image **504** are processed by logarithmic function blocks **506** and **508**, respectively, to enter the linear processing dotted block **510** equivalent to block **402** of FIG. **4**. After processing within block **510** is completed, the antilog is taken at function block **512** to produce the corrected image **514**.

Internal to linear processing block **510**, the logarithmic versions of the visible and infrared images are divided into high pass and low pass images with function blocks **520**, **522**, **524**, and **526**. These function blocks are selected such that when the output of the high and low pass blocks are added, the original input results. Further, the high pass function blocks **522** and **526** are equal, and the low pass function blocks **520** and **524** are equal. Under these assumptions, and under the further temporary assumption that the gain block **530** is unity, the topology in linear block **510** produces a result identical to the single subtraction element **408** for FIG. **4**.

Without the logarithmic function blocks **506**, **508**, and **512**, the split frequency topology shown in block **510** would not work. The output of a high pass filter, such as blocks **522** and **526**, averages zero because any sustained bias away from zero is a low frequency that is filtered out in a high frequency block. A signal that averages to zero in small regions obviously passes through zero within those small regions. If function block **540** were a division, as would be required without the logarithmic operators, then the high pass visible signal **542** would often be divided by the zero values as the high pass infrared signal **544** passed through zero, resulting in an infinite high pass corrected signal **546**, which obviously would give erroneous results. However, as configured with block **540** as a subtraction, the process is seen to avoid this problem.

The split frequency topology of FIG. **5** appears to be a complicated way to produce a mathematically equal result to that produced by the simple topology of FIG. **3** and FIG. **4**. However, by separating the high frequencies as shown in FIG. **5**, it is possible to overcome limitations in the scanner system by now allowing the gain block **530** to vary from unity. A typical scanner will resolve less detail in infrared light than in visible light. By letting gain block **530** have a value greater than unity, this deficiency can be controlled and corrected.

Often, however, the smudging of detail by a scanner in the infrared region relative to the visible region will vary across the image with focus shifts or the nature of each defect. By allowing the gain block **530** to vary with each section of the image, a much better correction is obtained. In particular, the value of gain is selected such that after subtraction with function block **540**, the resulting high frequency signal **546**